SECTION 9: BAS & CONTROLS
CONTENTS

DESIGN STANDARDS CHANGE LOG FEBRUARY 2013

No changes

9.1 INTRODUCTION

This section provides details of minimum requirements for the design, installation and operation of Building Automation System (BAS) services. The consultant is expected to produce their own specification incorporating the elements of the following information and submit all designs to the University's Manager (Engineering and Infrastructure) for review prior to any works commencing on site.

Please read this section in conjunction with rest of the Design Standards documentation.

9.2 GENERAL SYSTEMS AND STRATEGY

9.2.1 System Synopsis

The Parkville Campus comprises in excess of 120 buildings and approximately 50% of these are fitted with a building automated system (BAS). These systems vary in design and function from building to building. The older buildings generally have simple systems, used only for the control of basic air conditioning systems. The newer buildings generally have more sophisticated BAS systems that are integrated into the building's infrastructure, and providing monitoring and control for lighting, fire systems, power distribution and air conditioning.

Some of the existing BAS systems support remote access from a central server location but many are stand-alone and can only be directly interrogated locally at the device or system level.

The BAS systems that are present across the University's building portfolio do not conform to any single standard or architecture. The systems reflect a range of levels of sophistication whereby some buildings have newly installed fully functional BAS systems offering a single point of access, whilst others contain outdated stand-alone DDC devices.

The older systems can be unreliable, difficult to maintain, and in some cases unable to cope with changes to network infrastructure, such as IP address changes. However, the University has adopted a BAS strategy for all new and existing buildings based on the LON standard.

In 2007, the University commenced a program of BAS upgrades that has seen many of the obsolete stand-alone DDC devices replaced with new LON devices to provide a greater level of reliability and maintainability to the relevant buildings' control systems. The remaining balance of the obsolete devices will continue to be systematically replaced over the next few years, subject to funding availability.

Furthermore, in parallel with the replacement of the obsolete DDC devices, the University has installed many iLON 100 web interfaces to provide remote access and enhanced alarm functionality to the system 'front ends'.

Whilst significant funds have been spent over the last two years in upgrading both the 'back end' and 'front end' capabilities of existing BAS infrastructure, this level of funding will need to be maintained in order to complete the upgrade program.

It is also recognised that additional investment will also be required in order to fund a program of further system upgrades to consolidate the computing platform to a single server platform which will provide significant benefits to data logging and alarm handling functions.

9.2.2 Future Direction: The BAS Strategy

The University's BAS Strategy aims to consolidate all existing and future BAS sub-systems into a central building management system, so as to provide a single point of access for monitoring and control of all buildings through-out the campus. This centralised structure will provide the following operational benefits:

- A single point of access for monitoring and control of all buildings throughout the campus;
- More efficient servicing and system diagnosis; and
- Remote access support for monitoring and control of any building from any location throughout the campus and from off-site locations.

The strategy is underpinned by a commitment that all systems / devices must comply with the LON protocol and documented open standards for configuration and installation.

Furthermore, the University is committed to developing a centralised BAS management and support facility that will allow technicians to access any of the University's BAS systems from a central location or remotely via secure Internet access.

The following key outcomes are sought from implementing the BAS Strategy:

- Centralised BAS management tools, interface, reporting, trending, event and alarm logs;
- Remote web-access to all BAS systems;
- LON-based communication protocol;
- A single point of access for control and monitoring of all buildings throughout the campus;
- Use of a common set of BAS / DDC products that support the LON protocol and can be integrated onto the centralised BAS by our preferred BAS Services Contractor or Master Systems Integrator;
- The capability to integrate other building sub-systems (i.e. lighting, fire, security, energy and water metering, etc);
- The ability to implement energy efficient control strategies and functions such as time scheduling, load shedding, optimum start/stop, morning warm-up and night-purge, etc);
- Standardised alarm functionality integrated throughout the BAS with automatic alarm SMS paging and/or email notification to designated responsible persons for each area/system as advised by the University;
- No obsolete products, devices, protocols or systems.

To achieve these outcomes, the University has developed a three tier BAS Architecture to achieve the key outcomes identified above, as follows:

- Tier 1: Centralised BAS Management;
- Tier 2: Building Specific BAS Systems;
- Tier 3: Localised BAS/DDC Devices that support LON.

Note: Any VRV or proprietary air conditioning system or sub-system to be installed or upgraded as part of the BAS or any other building service should be fitted with a LON interface device to support communication with the BAS system. Wherever possible, installation of native open LON protocol devices is preferred.

9.2.3 BAS Migration Plans

The following table summarises the range and extent of the different BAS systems currently in place at the University's Parkville Campus, together with comments regarding the future migration plans for each system type.

SYSTEM TYPE	MIGRATION STRATEGY
INET	The University is phasing out this product range. All of these systems should be migrated over time to LON-based systems with a web interface.
Sigma	The University is phasing out this product range. All of these systems should be migrated over time to LON-based systems with a web interface.
IA Series Niagara	The Niagara 'R2' system supports the LON standard and conforms to the University's current BAS strategy. No immediate migration / upgrade works are proposed.
Satchwell IAC / MN-FLO	These proprietary products communicate via a gateway. These products should be upgraded to LON-based VAV products.
Invensys BAS 2800+	The University is phasing out this product range. All of these systems should be migrated over time to LON-based systems with a web interface.
Schneider Electric 'IA' Series	Current products support the BAS strategy and the LON standard.
Distech	Support the BAS strategy and the LON standard. Limited to VAV control.
Richards-Zeta	The University is phasing out this product range. All of these systems should be migrated over time to LON-based systems with a web interface.
Stand Alone Controls	These products should be replaced with LON-based products during any repairs / upgrade / refurbishment works.

The University's BAS installations are routinely being upgraded as repair, scheduled upgrade and refurbishment works are undertaken by the Asset Services Department of PCS. These changes are recorded in the 'BAS Building Summaries' document, maintained by the University's preferred BAS Services Contractor in consultation with Asset Services.

It is essential that any proposed refurbishment/upgrade works that are likely to impact on a current BAS installation must be discussed with and approved by the Engineering and Infrastructure / Asset Services Department prior to any tender submission to ensure that the proposed works will comply with the University's BAS Strategy and will not compromise / conflict with an existing BAS installation and the relevant building's BAS migration / upgrade plan. The same applies to the design and construction of any new building.

9.3 GENERAL REQUIREMENTS

9.3.1 Point Schedule

For any BAS design, consultants shall provide comprehensive point schedules detailing point descriptions, functions, types and any special requirements.

A copy of the 'As Built' revision points schedule shall be included in the BAS Operation & Maintenance manual for any BAS upgrade or new installation works and a hard-copy left in each field control panel.

Points schedules shall include as a minimum the point tag name, point description, point type (AI, DI, AO or DO), cable label, field device part number, field device description and comments columns.

9.3.2 BAS Networks

Any new BAS installation shall be connected to the University IT department's Ethernet TCP/IP networks. The University has developed a three-tier BAS architecture, as follows:

- Tier 1: Centralised BAS management tools for campus-wide monitoring and control with remote web access capability via remote access to the University's Ethernet TCP/IP network;
- Tier 2: Local LON-based control and communication protocol between devices within individual buildings;
- Tier 3: Localised BAS / DDC devices that support LON.

9.3.3 Criteria for Connection to BAS

The following equipment should be connected to the BAS as a minimum (where practicable):

- Mechanical equipment (chillers, boilers, fans, pumps, VSD's, AHU's, FCU's, VAV's, VRV's, etc);
- Electrical equipment (meters, power factor correction, UPS, etc);
- Lighting controls;
- Hydraulic systems;
- Access Control and/or fire system point monitoring as necessary.

9.3.4 Safety

No combination or sequence of operations of the BAS relays shall cause a condition which is unsafe, unhealthy or liable to cause damage to equipment.

Functionality which is essential for safe operation shall be mechanically interlocked. For example, the enabling of electric re-heat units via the BAS controller output shall be overridden by a hardwired interlock in the mechanical panel to prevent the electric re-heat from operating unless the hardwired interlock to that unit's air flow switch and/or other air-flow proving device is satisfied.

Appropriate delay times and run-on timers shall be incorporated wherever required to ensure dampers are open prior to fans starting, fans run-on following electric re-heat no longer required, etc.

9.3.5 Energy & Water Conservation

The BAS shall be capable of implementing sustainability Management programs including:

- Time programmed start / stop;
- Optimum start / stops;
- Supply air reset;

- Economy cycle;
- Lighting control where appropriate;
- Occupancy sensing, control & scheduling;
- Zero energy band/load reset;
- Thermal Energy calculation;
- Virtual energy/water meter calculation;
- Optimum plant operation. For example, ventilation to lecture theatres being controlled on air quality level. Occupancy sensors should be used where appropriate;
- Load shedding;
- Any other monitored points which may assist in producing energy saving or energy consumption statistics;
- Water, Gas and Energy consumption, demand and totalisation by day/month/year and associated reporting;
- Tenant billing ability;
- Advanced Water, Gas and Energy automated reports, custom reports, forecasting, unusual event detection and alarming, historical data record and back-up, comparison between individual meters, buildings and/or historical records (e.g. Last month versus same month of previous year, etc);
- Calculation of CO2 based on user-adjustable emission factors, definable for each component of the energy used (i.e. Ensure the consumption of zero carbon energy from alternate sources is not included in the calculation of total CO2 emissions).

9.3.6 LON Open Communication Protocol

The University has adopted LON as its standard communication protocol and any new installation must be capable of a full and transparent interface. All configuration files, bindings, graphics, etc. must be non-proprietary and able to be edited or amended by the University or its appointed BAS Master Systems Integrator / preferred BAS Services Provider.

For further details, refer to the appropriate current LonMark standards documentation.

9.3.7 Motion Detector Equipment

Spaces not used to a fixed time schedule shall be fitted with approved motion detectors, for example lecture theatres, teaching spaces, areas of infrequent use, etc.

The motion detector should be connected to the building's BAS system to control lighting and air conditioning in the affected areas.

9.3.8 Temperature Monitoring

Space temperature sensors shall be fitted in as many zones as are independently controlled by the heating / cooling system. In the case where a zone covers several rooms, sensors shall be installed in each room and the average temperature shall be used to modulate the heating / cooling valve.

A supply air temperature sensor shall be fitted to any heating / cooling coil to provide the BAS with a status of the plant and equipment.

9.3.9 Status Monitoring

Status shall be verified by verification of actual air/water flow. For example, the status of fans and pumps shall be provided by differential pressure transmitters/switches rather than contactor auxiliary contact points or other voltage free contacts that may not be reliable in all scenarios, for example should a belt break on belt driven equipment the contactor status is not affected.

Sufficient statuses shall be provided to the controller to allow the behaviour of the system to be monitored and diagnosed. If the BAS controls a pump or a fan, it shall monitor the pump or fan status. If the BAS controls a chiller or a boiler, all other associated parameters such as status, alarm, water flow and return temperatures, pump status, etc. shall be monitored.

Should the fire system override plant for emergency shutdown due to a fire alarm condition, this alarm shall be provided to the BAS controller as a status, an alarm raised on the BAS head-end and all associated alarms arising due to the fire override of plant shall be disabled to prevent nuisance alarms arising from the fire override condition.

9.3.10 Set Point Adjustments

Where appropriate for the design and safe and efficient operation of the device the BAS shall have the ability to override the temperature setpoint of mechanical plant provided all necessary conditions for setpoint reset are satisfied, as detailed in the BAS specification by the design consultant.

The BAS control shall prevent the override of setpoints beyond a reasonable range, as defined by the design consultant and/or plant manufacturer.

Occupants of a space shall not be provided with the facility to vary the set point.

9.3.11 Liaison

The Consulting Engineer shall liaise with the Engineering and Infrastructure / Asset Services Department, on BAS design and requirements, and obtain information on the existing BAS systems before commencing the initial design phase.

9.3.12 Labelling

All items of equipment associated with the BAS shall be suitably identified with traffolyte labels. Front End, field controllers, VAV boxes, valves, dampers, and sensors shall be labelled with identification that matches the relevant item programmed in the Front End.

All works shall be adequately documented so that every wire can be subsequently identified by wire number, colour code or termination frame location. All wires shall be numbered individually, and multi-core cables shall be terminated according to the standard colour code.

9.3.13 Commissioning

The BAS installation shall be commissioned and fully operational at the practical completion stage of the project. Commissioning procedures shall conform to Section 10: Mechanical Services and shall be carried out at the end / field equipment device to verify correct operation of equipment.

Pre-configured graphical trend logs shall be required to be pre-configured by the BAS contractor to enable effective operational performance analysis and tuning during the commissioning phase.

All commissioning / test reports are to be provided to the Engineering and Infrastructure / Asset Services Department and design consultants.

9.3.14 Training, As-Built Drawings, Operating & Maintenance Manuals

The specification shall require the BAS Contractor to instruct relevant University personnel and its nominated Contractors in the operation of the system at hand over.

As-built drawings, operating and maintenance manuals are to be provided as described in the CAD Standards Section of the University's Design Standards.

9.4 HARDWARE REQUIREMENTS

9.4.1 Input / Output

All interfacing with control devices shall conform to the following standards:

- Binary input:
  - Voltage-free contact;
  - Pulse input.
- Binary output: voltage-free contact;
- Analogue input:
  - 0–10V, 0–5V;
  - 4–20 ma;
  - Current device sensor;
  - Resistance device sensor;
  - Voltage device sensor.
- Analogue output:
  - 0–10V;
  - 4–20 ma.
- Service meters (gas, water, electricity): smart meter for electricity, gas and water consumption;
- Control relays shall operate at 24V AC;
- Other interfacing standards are only acceptable in unusual circumstances, where sensors and devices conforming to the above standards are not available.

9.4.2 Direct Digital Control (DDC)

The Direct Digital Control (DDC) Controller shall support LON and be a completely independent stand-alone unit with all firmware and software to maintain control on an independent basis (refer Section 9.2.3: BAS Migration Plans).

The Plant Controllers shall be enclosed in panels of similar construction to that specified for switchboards.

The system shall allow various controllers and sub-controllers to be networked and have the flexibility to readily permit modifications and additions of the control functions. Should one controller in a network fail, it shall not affect the performance of any others.

9.4.3 Front End and Associated Equipment

The Front End shall be a Windows-compatible PC with current Windows and Microsoft Excel software and LCD monitor. The specifications must be confirmed with the Manager (Engineering and Infrastructure) to ensure adherence to the University's IT standards.

9.4.4 Temperature Sensors

Temperature sensors shall be resistance, voltage or current device types with ranges selected to suit specific applications and have an error of no more than 0.3℃. Sensors shall be protected in a neat plastic or metal casing so that access to terminal strips and cabling can easily be achieved by removal of a cover.

Sensors shall not be locally adjustable. Where two or more sensors are provided for one zone, an average signal shall be used.

Sensors shall be mounted such that effects of radiation from heating / cooling sources (e.g. direct sunlight, heat generating equipment, supply air duct discharge grilles, draughts, etc.) are minimised.

9.4.5 Pressure Switches

Pressure switches shall have adjustable ranges and adjustable differentials to suit the application.

Pressure switches shall be sensitive enough (as low as 20 Pa if necessary) to ensure correct monitoring of small fans and shall have a switching differential of not more than 10% of the scale range;

Substitute the use of a pressure switch in favour of a current transformer with voltage free contact for status monitoring of very small fans where the duct pressure is unlikely to exceed the minimum sensible pressure.

9.4.6 Pressure Sensors

- Shall be suitable for the medium and the working temperatures and pressures;
- Shall be capable of withstanding a hydraulic test pressure of 1.5 times the working pressure;
- Connections shall be suitable for 8mm (¼") o.d. copper tube;
- Ductwork versions shall be supplied with air connections permitting their use as static or differential pressure sensors;
- The setpoint shall fall within 30%-70% of the sensing range of the sensor.

9.4.7 Damper Actuators

- Control voltage shall be 0–10V DC and power supply shall be 24V AC;
- Shall have a sufficient torque to open and close valves against the maximum out of balance pressure across them;
- Dampers shall incorporate spring return facility wherever necessary for fail-safe operation during fire mode or in the event of power failure;
- Mounting shall be rigid without distortion during operation. Linkages shall be fixed to shafts with grub-screws set in drilled recesses;
- Dampers shall be supplied complete with the necessary universal joints, cranks, linkages and mountings for the specified motorised valve or motorised damper;

- Dampers shall have position indicators unless fitted to terminal units. The fully open and closed positions shall be unambiguously marked.

9.4.8 Valve Actuators

- Control voltage shall be 0–10V DC and power supply shall be 24V AC;
- Valve actuators shall be linear in operation fitted with a manual override such that, in the event of a power failure, manual operation can be achieved;
- Valve actuators shall have a sufficient torque to open and close dampers against the maximum out of balance pressure across them;
- Valve actuators shall be supplied complete with the necessary universal joints, cranks, linkages and mountings for the specified motorised valve or motorised damper;
- Valve actuators shall have position indicators unless fitted to terminal units. The fully open and closed positions shall be unambiguously marked.

9.4.9 Wiring

The wiring for data communication between sensors, controllers, valve/damper actuators and any other BAS analogue or digital signals shall be shielded so as to not be susceptible to any electromagnetic interference such as electrostatic, magnetic, mode and cross talk noise.

All cabling shall be routed at least 500mm away from any low or high voltage power wiring and cross-over at right angles where required (no parallel runs).

Purple communications cabling shall be used for all BAS communications wiring.

Other wiring shall conform to the requirements of Section 7: Electrical Services.

9.4.10 Flow Measurement

Flow measurement devices shall include differential pressure transmitter/orifice plates, turbines, electromagnetic flow meters, ultra sonic flow meters, probe air velocity sensors or grid matrix air velocity sensors.

All flow measurement devices shall be calibrated during commissioning by calibrated independent equipment and appropriate scaling, offsets and/or K-factors applied to the measured values accordingly.

All calibration data including K-factors shall be documented in incorporated in the Operation & Maintenance Manual for the BAS.

9.4.11 Connection at the Mechanical Services Switchboard

Controls shall be designed so that the equipment will work safely and without risk to University staff or property in the event of a loss of power from the BAS controller.

Control cabling shall be wired to mechanical switchboards and be terminated in terminal strips provided in each board.

All control wiring shall pass through Auto-Off-Manual switches mounted on the Mechanical Services switchboard. These switches shall conform to the University's usage, and shall be provided with indicator lamps as follows:

- RED: ALARM, or device in FAULT
- GREEN: device switched ON (either manually or remotely)

In general, controllers shall be segregated, but close to a Mechanical Services Switchboard which shall supply the necessary power to the controller. Note: all cabling

passing through a mechanical services switchboard shall conform to appropriate standards (e.g. 500V insulation), but the controller shall be limited to extra low voltages (less than 35V), and data cable shall be rated accordingly.

9.4.12 Uninterruptible Power Supply (UPS)

The BAS is to be supported with an uninterruptible power supply (UPS) which must be capable of sustaining power to the controller and associated devices for a minimum period of thirty (30) minutes.

The BAS shall be of the type that in the event of mains failure the equipment supported shall not power down and reboot.

The system shall incorporate sealed batteries and include volt free contacts for connection to the BMCS for monitoring of 'battery low level' and 'charger fault'.

9.5 SOFTWARE REQUIREMENTS

9.5.1 Capabilities

The BAS software shall perform the following functions:

- Schedule start / stop;
- Optimum start / stop;
- Duty / standby cycling;
- Lead / Lag staging;
- Automatic temperature control;
- Maximum demand control;
- Control mode selection i.e. P, PI or PID;
- Calculation points;
- Run Hours Totalisation;
- Lighting control;
- Integration with scheduling programs (where applicable);
- Integration with metering devices;
- Scanning and alarm processing;
- Alarm functions (via SMS and email);
- Load shedding;
- Temperature set point reset algorithm;
- Night Purge, Warm-up mode, etc;
- Graphics reporting;
- Trend logging (Graphical);
- Global communication (including web functionality and remote access);
- OPC Server compliant;
- Tenant Billing;
- Energy Reporting.

9.5.2 User Friendliness

The BAS software shall be easy to operate and to program. Operators should be able to perform the following operations after a maximum of one day of training:

- View building parameters;
- Select relevant pages, systems and points;
- Acknowledge alarms;
- Turn on and off controlled points manually;
- Modify setpoints;
- Log trend data;
- Generate custom reports;
- Diagnose system performance;
- Diagnose device communication failures/alarms.

9.5.3 Graphics

Graphics shall be included for ease of system operation. Graphics pages shall include but will not be limited to:

- Floor plans with room temperatures, sensor name & associated unit;
- Chilled water plant;
- Heating hot water plant;
- Air handling units;
- Energy and water consumption data;
- Tabular information where appropriate
- Graphics Standards shall be provided by the Engineering and Infrastructure / Asset Services Department.

9.5.4 Communication

Any BAS installed on University properties shall provide user interface functions to responsible staff via the University's computer network. This will allow the relevant staff to:

- Program remote controllers from the central BAS control room;
- Receive alarm messages, automatically process and convey them to the Asset Services Department via the University's IT network;
- View live and historical trend data from the remote stations.

Within each of the particular networks, the controller shall have the ability to broadcast data, to transmit input/output points as global points onto the network for use by other controllers, which are able to capture data for internal processing. If one controller fails, it shall not affect the other controller's performance

Any device communication failures shall raise an alarm on the BAS head-end.

9.5.5 Reporting

The BAS software shall display live and historical trend data on demand.

The software shall allow the operator to select points, groups of points, and mechanical systems through user friendly graphics functionality.

The software shall provide graphic pages for all relevant building functions.

Include advanced Water, Gas and Energy automated reports, custom reports, forecasting, unusual event detection and alarming, historical data record and back-up, comparison between individual meters, buildings and/or historical records (e.g. Last month versus same month of previous year, etc).

9.5.6 Trend Logging

The BAS shall have the ability to store logged data, including all input/output points, for a minimum period of two years without manual data handling. Trend data must be easily retrievable for export to Excel spreadsheet.

Each point shall have individual time scales for system reporting. The time scale shall be adjustable in one minute increments.

It shall also be possible to register the start/stop sequence of any selected plant using the trend log, such as: main plant, floor/zone manager, services settings, water temperatures, etc.

Trend logging functions should be easy to query, manipulate trend periods, and adjust from the same graphics page.

The system shall have the facility for printing out any display log.

9.5.7 BAS Alarms

Whenever abnormal conditions arise, alarms shall be generated and the alarm messages shall be displayed on the BAS head-end alarm log and simultaneously generate SMS and email messages, as appropriate to the application.

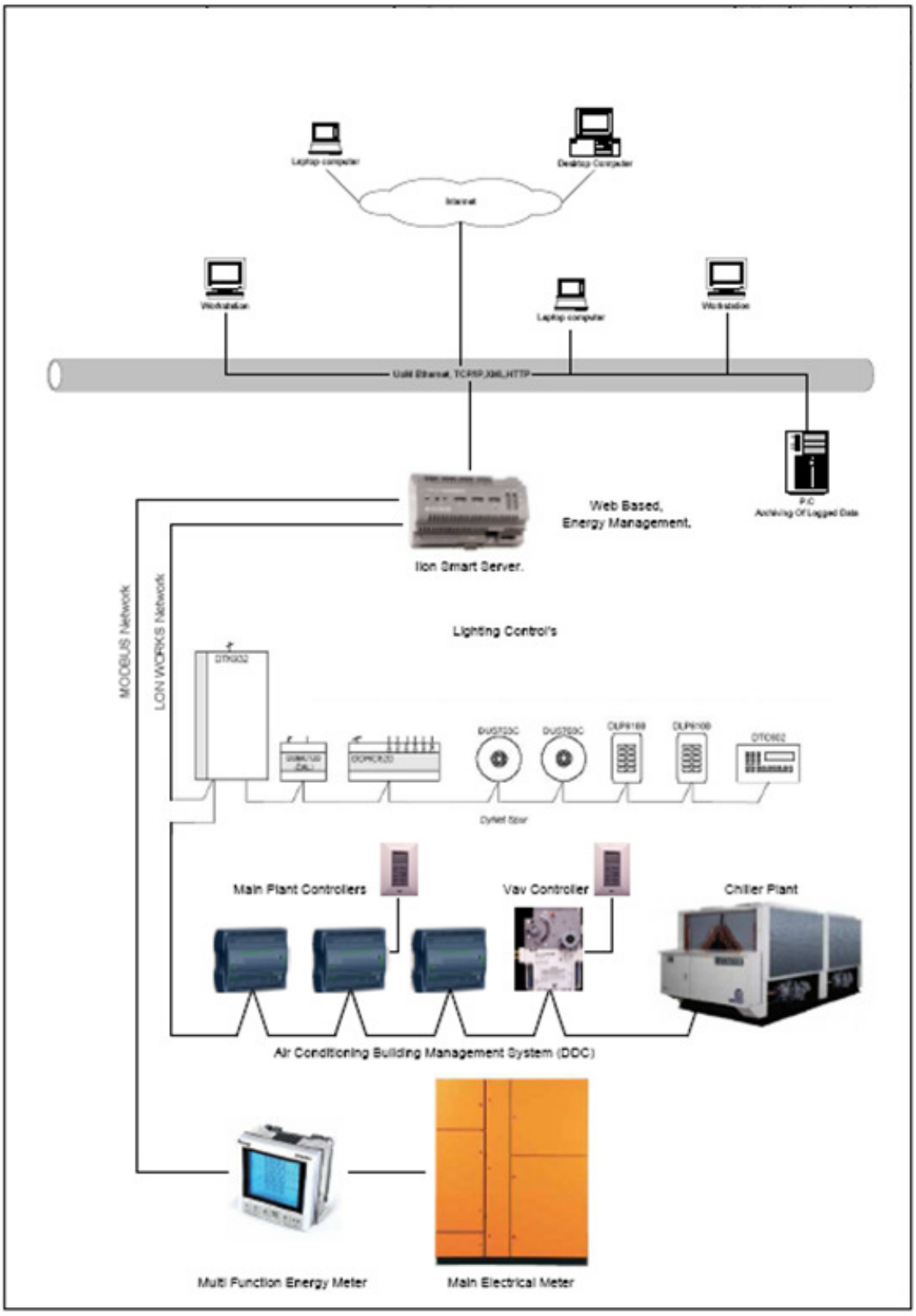
When an alarm condition is generated, the relevant head-end terminals on the system shall beep continuously until the alarm is acknowledged at any terminal.

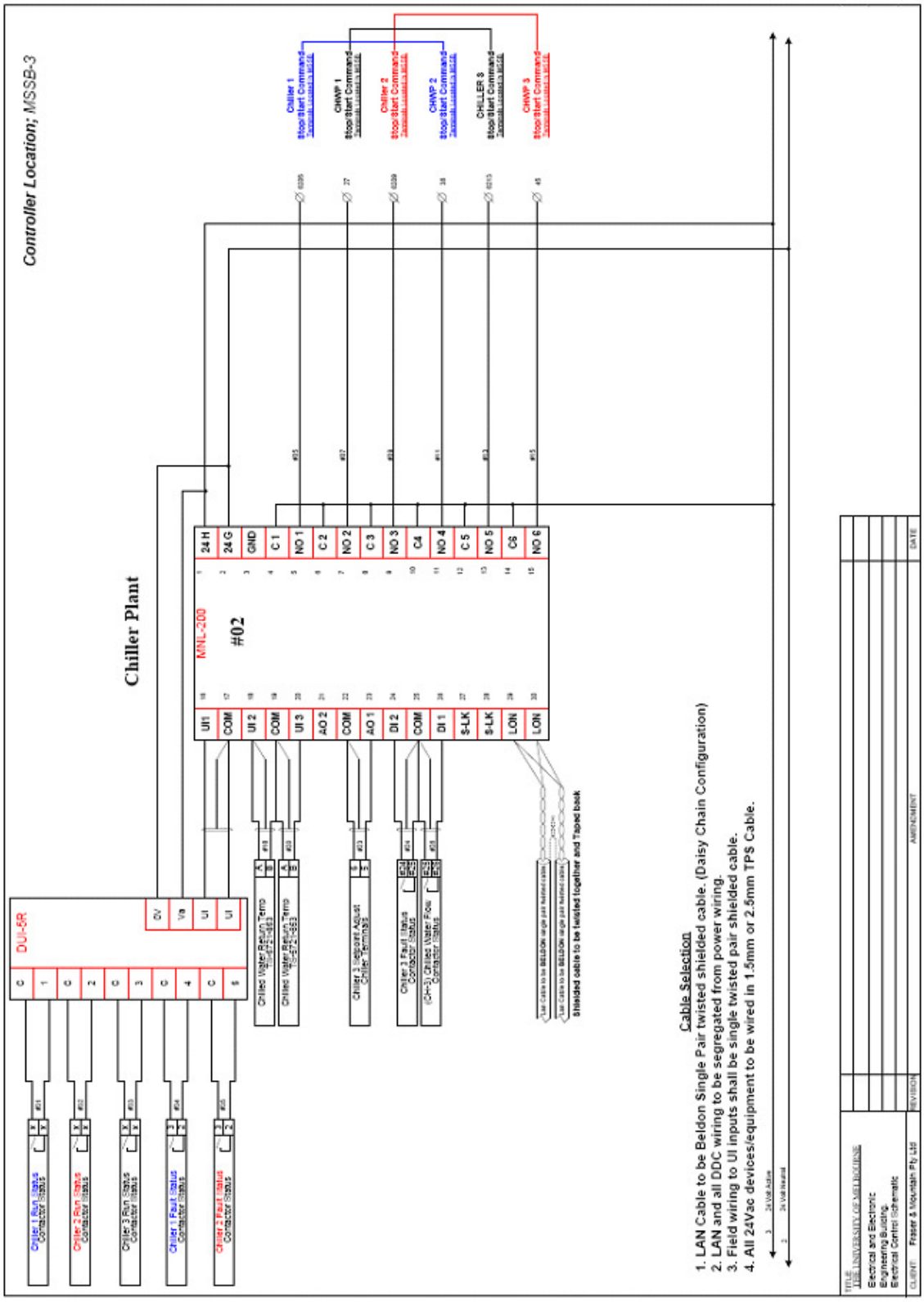
Alarm signals shall be sorted and printed out at relevant printers with clear action messages.

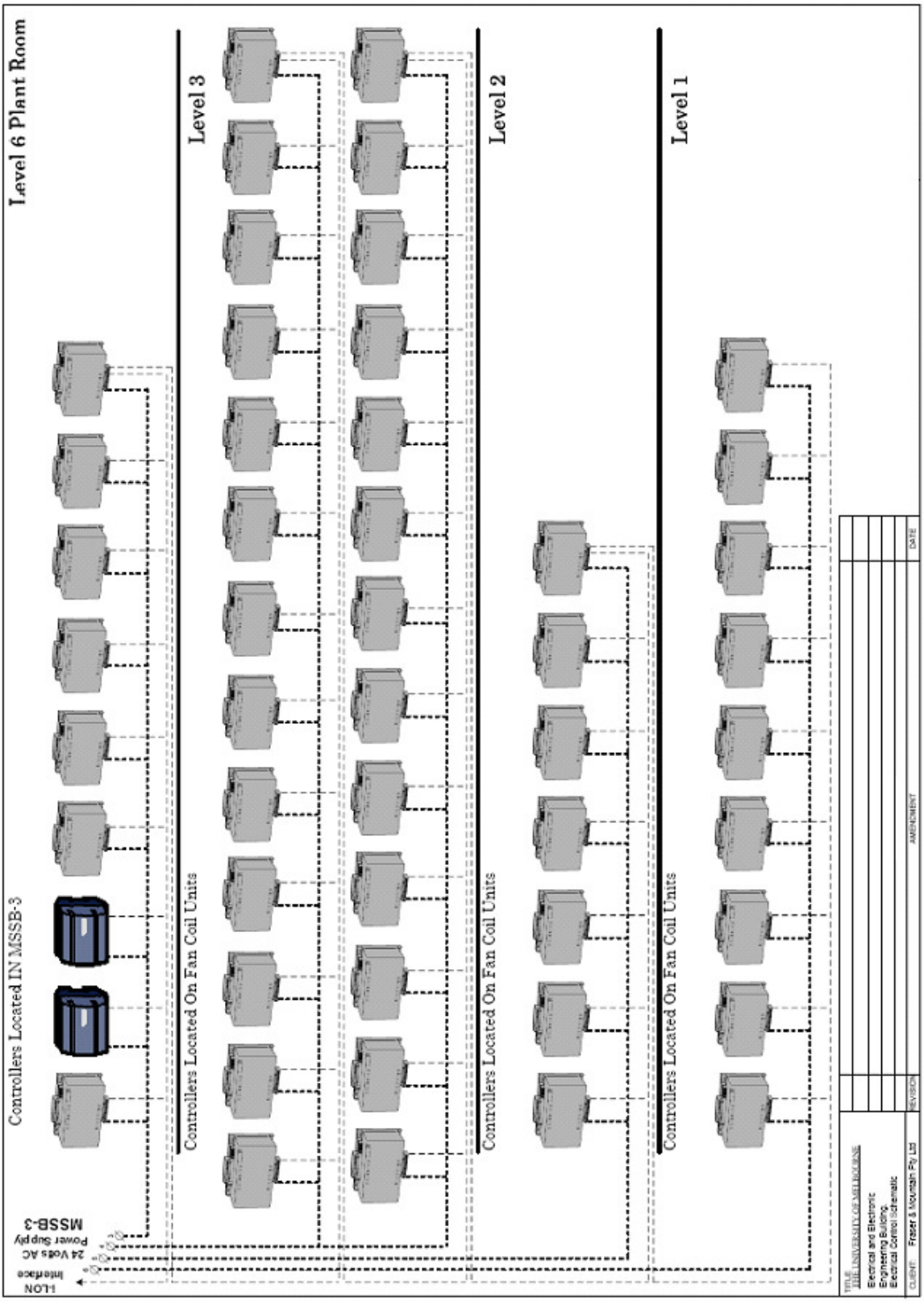
The BAS shall prioritise alarm groups. Critical alarms shall be sent to nominated Asset Services Department staff for immediate action via SMS and email.

All devices and third party equipment shall be configured such that the BAS ‘alarm’ or ‘fault’ contact is in the alarm condition upon loss of power at the device/equipment.

9.6 SCHEMATIC DIAGRAMS




Controller Location; MSSB-3
Chiller Plant
#02
MNL-200
DUI-6R
Chiller 1 Run Status
Chiller 2 Run Status
Chiller 3 Run Status
Chiller 1 Fault Status
Chiller 2 Fault Status
Chiller 1 Start/Stop Command
CHWP 1 Start/Stop Command
Chiller 2 Start/Stop Command
CHWP 2 Start/Stop Command
CHILLER 3 Start/Stop Command
CHWP 3 Start/Stop Command
Chilled Water Return Temp
Chilled Water Return Temp
Chiller 3 Setpoint Adjust
Chiller 1 Fault Status
(CH-3) Chilled Water Flow
Shielded cable to be twisted together and Taped back
Cable Selection
1. LAN Cable to be Beldon Single Pair twisted shielded cable. (Daisy Chain Configuration)
2. LAN and all DDC wiring to be segregated from power wiring.
3. Field wiring to UI inputs shall be single twisted pair shielded cable.
4. All 24Vac devices/equipment to be wired in 1.5mm or 2.5mm TPS Cable.
24 Volt Active
24 Volt Neutral
THE UNIVERSITY OF MELBOURNE
Electrical and Electronic
Engineering Building
Electrical Control Schematic
CLIENT: Fraser & Mountain Pty Ltd
REVISION
AMENDMENT
DATE


Level 6 Plant Room
Controllers Located IN MSSB-3
Level 3
Controllers Located On Fan Coil Units
Level 2
Controllers Located On Fan Coil Units
Level 1
Controllers Located On Fan Coil Units
LON Interface
24 Volts AC Power Supply
MSSB-3
THE UNIVERSITY OF MELBOURNE
Electrical and Electronic Engineering Building
Electrical Control Schematic
CLIENT: Fraser & Mountain Pty Ltd
REVISION
AMENDMENT
DATE